Planning for Urban Resilience through Biomimicry in the Design of Public Waterfront Spaces

A Thesis Presented to the Faculty of Architecture, Planning, and Preservation
COLUMBIA UNIVERSITY

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Urban Planning

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May 2019

Abstract

The New York City waterfront is an imprecise combination of nature and artifact. Urban waterfronts have evolved from natural landscapes to industrial manufacturing areas, and increasingly to areas of mixed-use. With that evolution comes waterfront public spaces, such as riverfront parks and shore public walkways that also need to react and adapt to a changing climate. However, there are technological advancements and policy implementation time lags inherent in the built environment that have affected the performance of these spaces in times of human-made and natural climate disasters. This study examines the creation of public space in waterfront redevelopment with the emerging field of climate-reactive design for urban resilience in the context of New York City.

This study is done in relation to the United Nations' Sustainable Development 13th Goal "Climate Action", New York City's OneNYC initiative, and the United States Army Corps of Engineers (USACE) New York-New Jersey Harbor and Tributaries Coastal Storm Risk Management study. These three institutional reports aim to fight against climate change through the collective reduction of greenhouse gas emission and strengthening our built environment with physical interventions. Through qualitative analysis, this study reveals how planning and development mechanisms interact with climate resilience strategies, specifically through the lens of open space, and argues that a biomimetic approach to urban design can help mitigate the effects of time lag on open spaces.

Keywords:

biomimicry, climate change, community engagement, open space, urban design, waterfront redevelopment

Acknowledgments

To Douglas Woodward and Graham Trelstad,

Thank you both for your commitment to thoughtful urban design and planning, and your continuous wisdom and guidance on this thesis and throughout my time here.

To the friends I've made here at Columbia,

Thank you for the late nights in Avery, Fayerweather, and random nooks across the city. I can't wait to see what you all achieve.

To the family I was lucky enough to have at the beginning

and to the chosen family that I made along the way,

Thank you for your endless support, for dealing with my terrible jokes, and for believing in my lofty dreams. I couldn't have done any of it without you all.

To the City of New York,

Thank you for taking care of my family at their start in the United States and welcoming us back during my time here as student. This thesis is dedicated to your communities that have been adversely affected by natural and human-made climate disaster.

List of Abbreviations

CEQR – (New York) City Environmental Quality Review

DCP – New York City Department of City Planning

DEC – New York State Department of Environmental Conservation

DPR – New York City Department of Parks and Recreation

EPA – Environmental Protection Agency

FEMA – Federal Emergency Management Agency

NOAA – National Oceanographic and Atmospheric Administration

UN – United Nations

USACE – United States Army Corps of Engineers

WCS – Wildlife Conservation Society

WRP – Waterfront Revitalization Plan

1. *Introduction*

This thesis seeks to learn how bio-mimetic design can augment the climate mitigation and resilience of waterfront public spaces through integration within urban planning processes. Two types of biomimetic design strategies will be explored – a restoration of historic ecological conditions and the implementation of emerging architectural biotechnologies. In researching these design considerations, a framework for biomimetic strategies will be built and tested alongside planning mechanisms that apply to public open space. Both conceptual frameworks operate in conjunction with existing resilience projects that are in their nascent stages, under construction, or are complete as of Spring 2019.

New York City has always been a leader in maintaining open space as a part of the public realm, even as it evolved into a largely concrete, urban city. Greenway networks were developed in the late 1800s with the Parks Association of New York City advocating for the protection of natural areas and the development of parks. Parks, such as Riverside Park in the Upper West Side neighborhood of Manhattan were designed to resemble nature and to offer respite from an increasingly built out New York (Olmsted, 1865). The environmental movement at the time saw the protection of the environment merely as tool to address squalor and poor public health.

However, in recent years, the need to protect the environment has grown to include combatting global climate change. Former Mayor Michael Bloomberg, in his 2009 PlaNYC proposal, sought to increase investment in green technologies such as solar panels and vegetative roofs. This was done for the benefit of public health but was understood to have the ancillary benefit of heightening New York City's resiliency to harsh weather conditions.

Today's socio-political climate, then, has environmental issues at the forefront. Urban resilience is a growing field of study and is institutionalized in the United Nations' Sustainable

Development 13th Goal “Climate Action”, that is calling for radical action to prevent 1.5 degrees Celsius of climate warming.[1] At a local level, New York City Mayor Bill de Blasio launched OneNYC to address a series of challenges in the city's aging infrastructure, the tri-state region's growth, and climate change in 2014. Two of the guiding principles of OneNYC are "Our Sustainable City" and "Our Resilient City" both of which aim to fight against climate change through the reduction of greenhouse gas emissions and strengthening our built environment (City of New York, 2014 - 2018). Furthermore, recent developments at the federal level seek to intervene in strengthening the climate resilience of New York City as well. The United States Army Corps of Engineers New York-New Jersey Harbor and Tributaries Coastal Storm Risk Management Study aims to reduce flood risk in the New York Metro area and creates decision models of five scenarios that range from “softer” land-based interventions to “hardscape” in-water infrastructure.

2. Research Question

This thesis explores the ways in which the practice of urban planning and the governmental frameworks that apply to New York City can interact with and evolve using climate-resilient design strategies in the redevelopment of waterfront public spaces.

3. Research Design

[1] According to the Intergovernmental Panel on Climate Change, 1.5 degrees Celsius is a widely accepted upper threshold by which the warming of the Earth’s surface air and sea temperature can “safely” increase.

A qualitative observational study was employed to describe the efficacy of existing waterfront public spaces in climate resilience. Waterfront public spaces created by the New York City *Zoning Resolution* that were inundated during Hurricane Sandy were visited and observed starting in the fall of 2018 to the spring of 2019. Retrospective data collection, publicly available through municipal and federal government websites, augmented what was learned from these site visits.

For spaces that were conceptual, not fully built, or outside of the study area, semi-structured interviews of site designers, governmental officials, and neighborhood leaders were conducted to better understand planning processes, design considerations, and roadblocks to development. Interviewees were asked about their involvement in projects and development and were asked to clarify planning processes and design considerations researched prior to the interview. Individuals were identified though organization or agency websites and contacted via email to request interviews and are anonymized in this paper to protect their identity. Additional research, including analysis of post-disaster aerial imagery and mapping of spatial data was qualitative in nature.

4. Literature Review + Conceptual Framework

4.1 Waterfront redevelopment

The literature on urban waterfront redevelopment is wide. The rise of urbanization and the growth in population in metropolitan areas has caused cities around the world to eke out useable land wherever they can find it. As cities shift from industrial centers to service-based economies, tracts of land once dedicated to manufacturing are becoming prime areas for residential and commercial redevelopment (Vormann 2015). Many of these manufacturing operations were water-dependent or water-enhanced and thus were situated in close proximity to waterfront areas (Bowling 2013).

However, the creation of public space is not often a factor in this new paradigm of waterfront redevelopment. Literature on manufacturing redevelopment outside of a New York context ignores liminal spaces created in this process. The importance of transitional spaces and urban interaction in the United States arose in the mid-20th century. Researchers changed the narrative of urban renewal and the increasing popularity of suburban living by contrasting strong communities connected by well-designed public spaces in dense urban neighborhoods. (Jacobs 1961 & Whyte 2001) However, this area of research is at the forefront in New York City as old infrastructure like the High Line Park in Manhattan and the Gowanus Canal in Brooklyn reclaim and repurpose aging infrastructure for public space (Brown, Grant 2005 & Gravel 2016).

Figure 1: Newtown Creek Waterfront in the 20th Century, CityRealty (n.d.)

Figure 2: Rendering of Newtown Creek at Vernon Boulevard, Riverkeeper (2018)

4.2 Governmental framework

4.2.1 City government

Current academic literature is limited on specifically waterfront public spaces, but city agencies offer extensive guidelines on how to incentivize and build these spaces (City of New York, 2018). New York City specifically has been looking at innovative ways of providing public access to waterfront spaces, with a number of planning studies that take stock of shoreline conditions and urban connections to waterfront space (City of New York, 2014).

The New York City Department of City Planning is the regulatory body that helps create these waterfront public spaces through private development. The City Planning Commission also operates as the City Coastal Commission which developed a Waterfront Revitalization Plan (WRP) with New York State government that sought to establish policies for waterfront planning that supported the preservation of publicly accessible waterfronts and allowed for development that ensured environmental conservation. The WRP has gone through a series of iterations based on comprehensive waterfront plans and now consists of ten policy "goals" with which waterfront projects, including public spaces, must stay consistent. These goals include an expansion of public access to the water, improving water quality, a restoration of the natural waterfront, and increasing climate resilience. Following the Revitalization Plan, the first Comprehensive Waterfront Plan was developed by DCP in 1992. It laid out long-term goals which make waterfront public access available across all five boroughs of New York. The primary recommendation was to provide linear public access across private and public lots. And one year later in 1993, Waterfront Zoning was added to the *Zoning Resolution*.

Waterfront Zoning began as a means to provide public access to the waterfront during the redevelopment of property within a waterfront block, which are those that are adjacent to or

intersected by the shoreline of a body of water. There are triggers in Waterfront Zoning that require developments to provide different forms of access to the waterfront[2]. This access can be as extensive as a new neighborhood park or as minor as maintaining a visual corridor to the body of water. The city's governmental framework for Waterfront Zoning sets the standards by which waterfront public spaces need to adhere, but is prescriptive in its regulations, dictating details such as linear feet of seating and number of canopy and ornamental trees that need to be provided within a space.

As this thesis explores the implementation of bio-mimetic design strategies in planning strategies, the New York City Department of Parks and Recreation and the spaces that which they have jurisdiction over will be used as a comparison to spaces built under DCP Waterfront Zoning regulations.

4.2.2 State government

Since 2016, the New York State Legislature has written commitments to climate protection, embodied in the Climate and Community Protection Act (S.2992 / A.3876). This bill mandates a state-wide shift to renewable energy in all economic sectors and reallocates funding toward communities that are vulnerable to climate disaster. Forty percent of funds would go to a "greening" of the state economy, including funding toward the New York State Department of Environmental Conservation (DEC). DEC is a regulatory body that was designed in the 1970s to "protect and enhance" the environment, looking at six different functions[3]. The Division of

[2] New York City Department of City Planning (August 2018) Zoning Resolution Article VI, Chapter 2 – *Special Regulations Applying in the Waterfront Area*

[3] These regulations include Fish and Wildlife, Lands and Forests, Air Resources, Quality Services, Resource Management Services, General Regulations, State Aid, Law Enforcement, Independent Agencies within the Department, and the Division of Water.

Water identifies seventeen major watersheds in New York State. New York City's waterways are in two: The Lower Hudson River, and the Atlantic Ocean/Long Island Sound. New York State has a series of projects in these two watersheds that aim to heighten climate resilience, considering issues of sea-level rise, storm surge, flooding, and change in temperature.

This study is focused in the NYS Marine Coastal District, in which eleven programs focus on the conservation of waterways and biomes of New York City.

4.2.3 Federal government

There are agencies that work at the federal level to develop strategies for environmental protection and restoration, namely the Environmental Protection Agency (EPA), the Federal Emergency Management Agency (FEMA), the National Oceanographic and Atmospheric Administration (NOAA) arm of the US Department of Commerce, and The US Army Corps of Engineers (USACE).

The EPA commissions research that guides practice and policy across the country. Their research, then, is translated into targeted grant funding, in times for resilience projects[4]. In times of emergency, FEMA circumvents both city and state regulation to respond to disaster situations.

FEMA also produces flood insurance rate maps (FIRMs) that indicate areas that are at risk of flooding and dictate the rate at which building owners are charged for flood insurance. These maps are developed using in-house projections corroborated by external experts and property owner reports. Municipal building code is also tied to these maps, dictating the base flood elevation of buildings in the floodplain.

[4] The EPA collaborates with FEMA on projects branded as "Smart Growth Strategies for Disaster Resilience and Recover" and curates tools based on lessons learned from those projects that other municipalities can use.

The National Oceanic and Atmospheric Administration offers reporting on waterways and climate conditions. In 2012, they had published spatial data based on their tracking of New York City's flood inundation after Hurricane Sandy[5]. The resulting map showed that the water line had risen to many parts of the historic shoreline of New York City, flooding a number of developments built on infill. A notable exception was Battery Park City in Lower Manhattan.

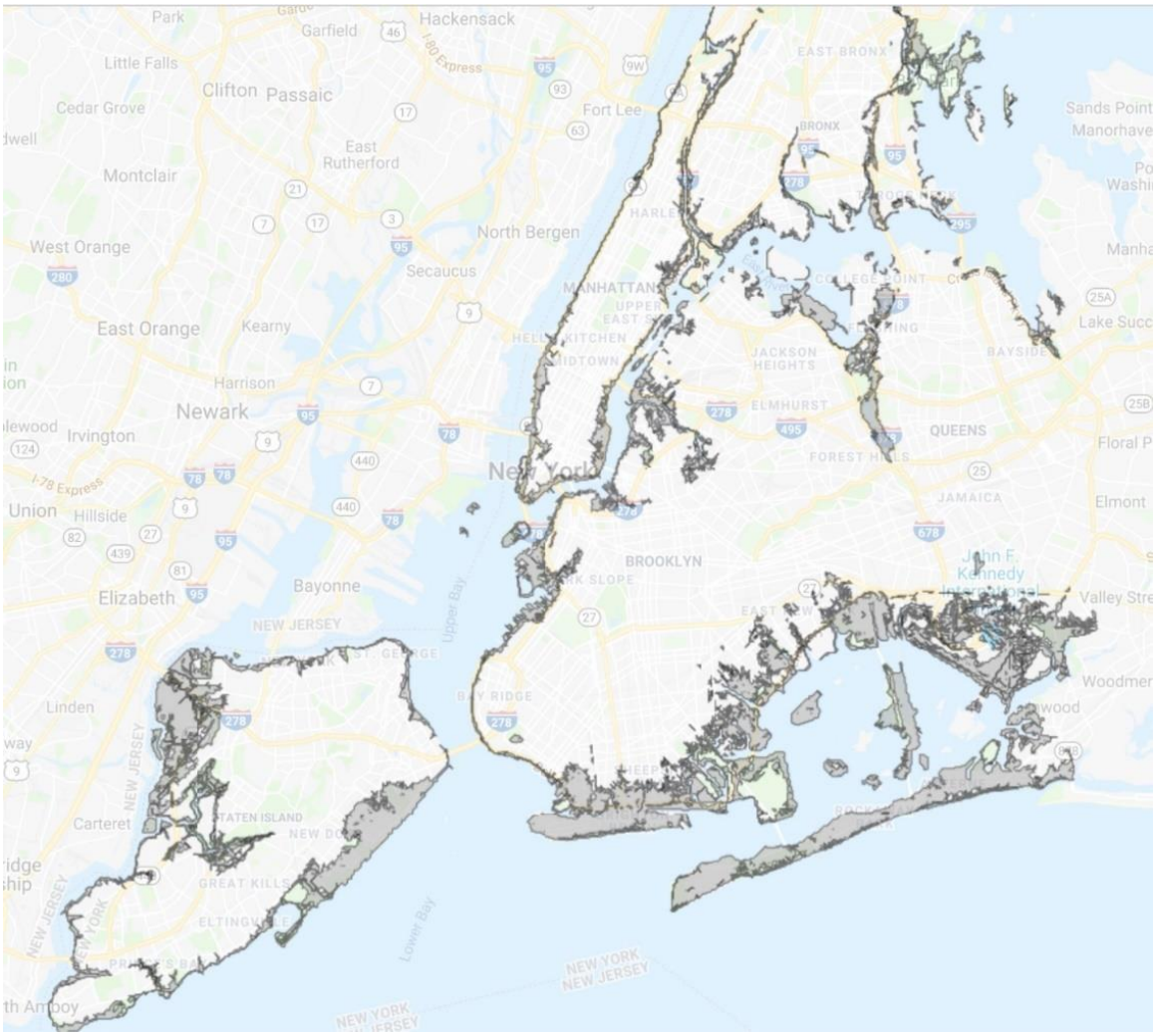

Figure 3: Hurricane Sandy Inundation Zone, NYC Open Data (2018)

[5] The 2012 North Atlantic storm commonly known as "Hurricane Sandy" is often referred to as "Superstorm Sandy" due to a change in its characteristics when it made landfall. The designation "hurricane" will be used in this paper for clarity purposes.

USACE researches and executes large-scale construction projects, many of which intersect the natural water system and aim to redirect their flow away from areas inhabited by humans. The New York District operates the Defense Environmental Restoration Program and collaborates with the EPA on Superfund remediation projects. Most recently, USACE has been studying flood mitigation techniques in this research's area of interest. A 2015 study on the North Atlantic region was framed around the infrastructural damage caused by Hurricane Sandy in 2012. This research led to a proposal for development of risk management measures. A February 2019 Harbor and Tributaries interim report was published discussing strategies that would alleviate effects of future climate-based disaster in the region based on in-house modelling, seen on the following page.

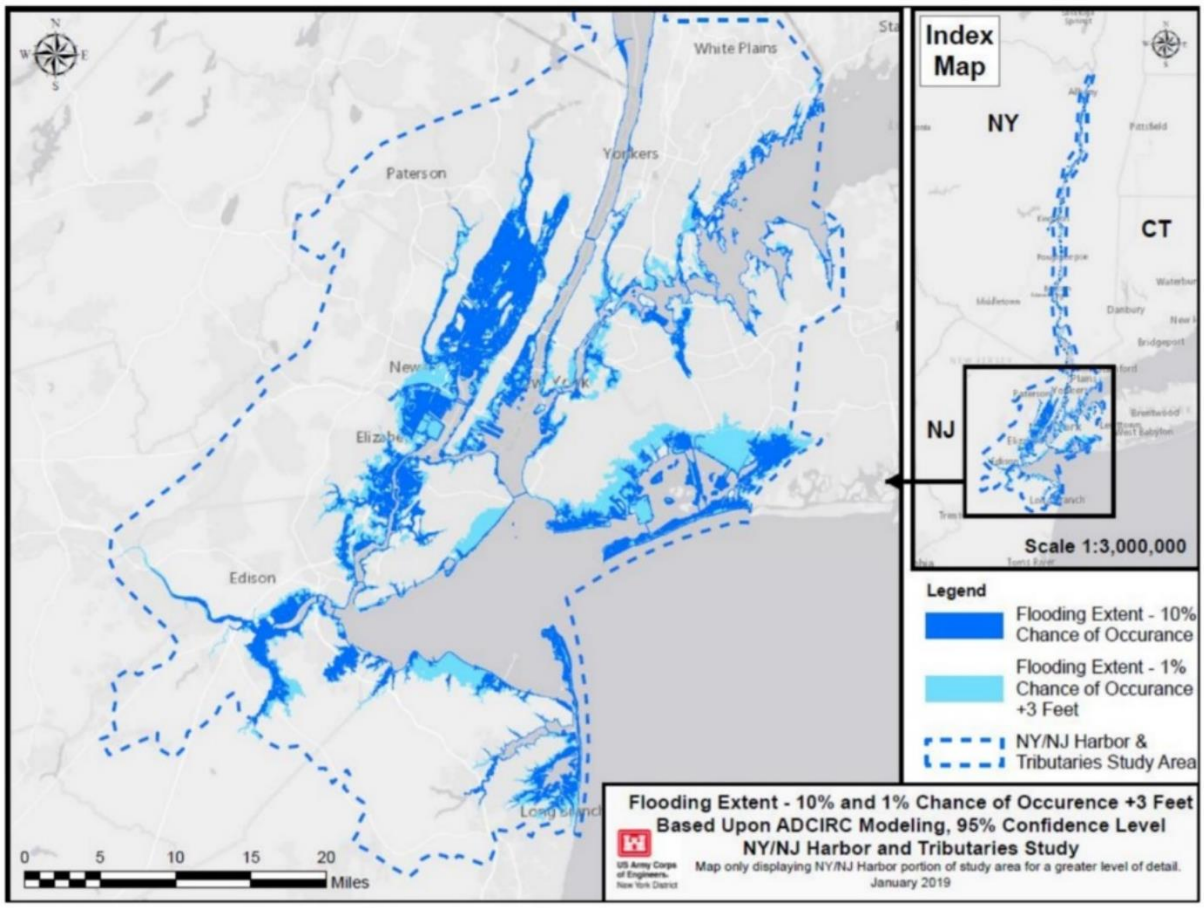

Figure 4: 3-foot flooding 1% and 10% chance projections of the Metro Region, USACE (2019)

The USACE proposals are ordered in terms of hardscape intensity.

- Proposal 1 is a five-mile-long at the mouth of the New York-New Jersey Harbor in the Atlantic Ocean. This barrier is projected to cost $620 million dollars as of 2018.
- Proposal 2 is a levee system that integrated five smaller in-water barriers, all of which are located in New York City waterways: Arthur Kill by Staten Island, the Narrows and Sandy Hook, both of which are between Staten Island and Brooklyn, Jamaica Bay between Brooklyn and Queens, and Pelham Bay in the Bronx.
- Proposal 3 A and B offer various locations for bay and basin barriers, floodwalls, and levees across New York City and the New Jersey Hudson Riverfront.
- Proposal 4 is to construct smaller storm barriers at locations identified in Proposal 2.
- Proposal 5 focuses on strengthening shorelines through nature-based interventions done in target areas: East Harlem, the Gowanus Canal, Newtown Creek, Jersey City, Moonachie, and the Meadowlands.

It is evident that the waterways of New York City and the spaces that are adjacent to them are subject to a number of governmental regulations. The following graphic published by the Mayor's Office shows the extent of federal, state, and city-funded climate resilience projects underway as of Fall 2018. The USACE Harbor and Tributaries project is absent as its final build has not been selected nor has received full funding.

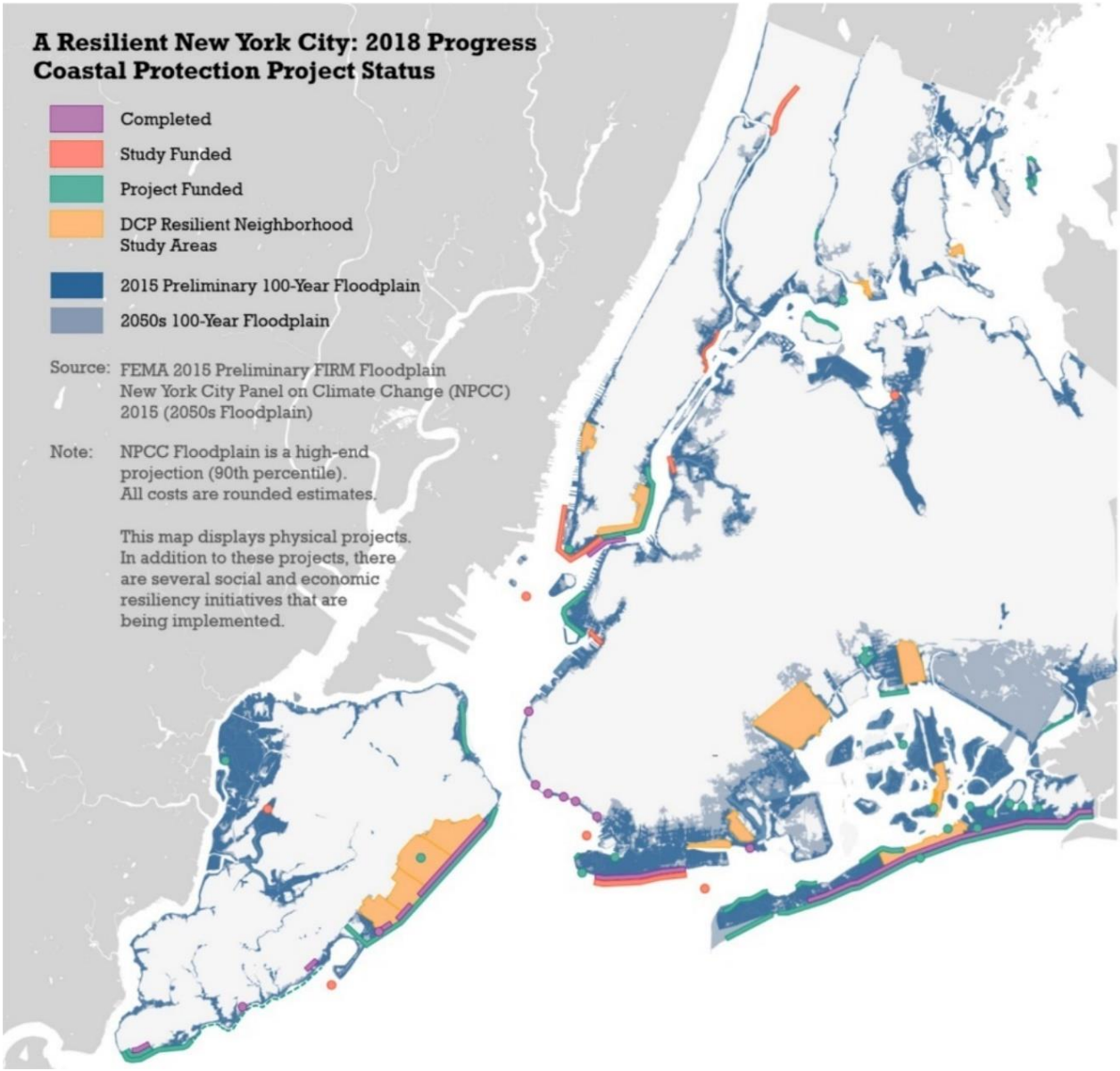

Figure 5: Coastal Protection Projects in New York City, OneNYC (2018)

As recent climate events such as Hurricane Sandy are only increasing in frequency, transitional spaces between developments and waterfronts that were built in previous years have not been able to cope with the intensity of these storms[6] as evidenced by the sheer number of projects coming in through all levels of government. Six years after Hurricane Sandy, many communities' open spaces are left either unrepaired due to the glut of governmental processes or repaired but no stronger than they were before the storm. This thesis, then, aims to continue the tradition of highlighting New York City as a laboratory for developing quality public spaces, but through the lens of climate change mitigation and resilience by way of bio-mimicry and governmental interventions.

4.3 Biological processes in urban planning

If the practice of urban planning shapes how humans experience the built environment through the regulation of land use, then uncontrolled natural processes are characteristically at odds with such practice. This divide is illustrated in by the 17th century intellectual movements of Romanticism and Pastoralism, both of which sought to offer respite from an increasingly industrialized world. It is in these eras that humans documented their love of nature through art, music, and literature while simultaneously moving the natural landscape elsewhere through the urbanization of cities. Shown below is *The Arcadian*, one painting from of New York-based Thomas Cole's series entitled *The Course of Empire*. *The Arcadian* is what he believed to be humanity at peace with nature. Humans have applied the lightest touch of development, but are

[6] McPherson, C. (2018, October). Six years after Sandy, a rising tide of development puts Coney Island at risk. FastCompany. Retrieved from https://www.fastcompany.com/90257901/six-years-after-sandy-a-rising-tide-of-development-puts-coney-island-at-risk

preparing to grow the empire, so to speak. He has captured a moment concretized in the term "biophilia" which was first coined by biology scholar Edward O. Wilson in his 1984 book *Biophilia.* He hypothesized that humans are innately drawn to natural processes and defines it as an "urge to affiliate with other forms of life." Notable examples of biophilia at the urban scale ca be seen in East Asian countries, as will be discussed in a later section.

Figure 6: The Arcadian, Thomas Cole (1836)

As humans begin to recognize the importance of open space as a proxy for nature in their cities, the importance of incorporating nature into our built environment through urban planning practice also heightens. One way in which design practices have incorporated this innate draw to nature is through mimicking its processes. This act is increasingly known as "bio-mimicry," a portmanteau of "biological mimicry". Bio-mimicry in itself is a neologism for a long-standing

tradition of design inspired by or informed by natural processes. Neologisms such as biophilia and bio-mimicry have often been criticized for their inefficiency in communicating a clear goal, relying on new branding that can "take on many forms" (Haila, 2017), pliable to whatever purpose may benefit from association to nature. This practice upends aspects of the dichotomy presented by Pastoralism and allows for a blurring of the built and the natural in this era, identified as the Anthropocene, a time period that where humans have been the dominant force in climate and the environment[7].

One way to fight anthropogenic climate change is to allow nature to guide architectural, landscape, and urban design considerations through the restoration of historical conditions (Watson, Adams, 2010). Their *Design for Flooding* aims to tackle climate resilience through the collection of "regenerative" landscape design strategies that take a more site-specific, as opposed to a one-size-fits-most" paradigm developed by American landscape architecture scholar John T. Lyle in the 1970s. This research, instead, accepts the assertions made by Scottish landscape architect Ian McHarg in his 1969 book *Design with Nature*. He argues that many landscape architectural problems to which humans have tried to prescribe their solution already have elegant nature-based solutions. As fields of urban design and planning increasingly intersect with product design and technology, bio-mimicry will act as a reminder to think critically about how nature performs when left to its own devices.

[7] Stromberg, J. (2013). What is the Anthropocene and Are We in It? *Smithsonian Magazine,* January 2013. Retrieved from https://www.smithsonianmag.com/science-nature/what-is-the-anthropocene-and-are-we-in-it-164801414/

4.4 Conceptual bio-mimicry framework

In order to understand how bio-mimetic design processes would work in the context of planning, an exploration of techniques is done in the context of the more-established field of bio-mimetic materials science and industrial design.

The Biomimicry Institute, a non-governmental organization focused on the integration of biologically inspired design and practice in education, provides a "Biomimicry Taxonomy" through their AskNature project. The taxonomy categorizes functions of bio-mimetic design processes by the desired end goal and provides a framework that can be applied to human-scale products such as furniture. Furthermore, it breaks bio-mimetics into three levels: One – *Natural Forms*, or the way something looks, Two – *Natural Process*, or the way something is made, and Three – *Natural Ecosystems*, or the way something contributes.

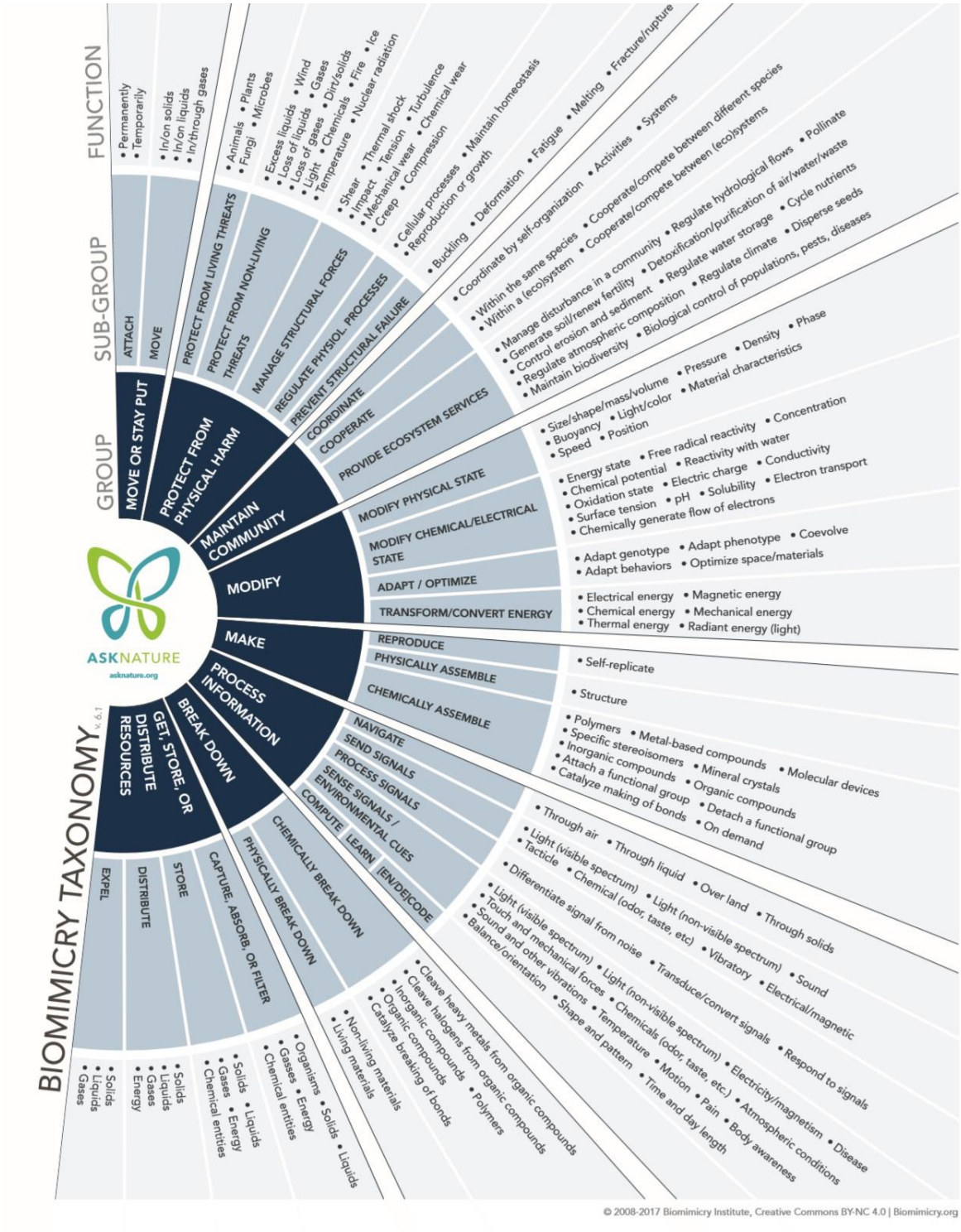

Figure 7: Biomimicry Taxonomy, AskNature (2017)

The most notable limitation of this framework is its lack of applications beyond the human-scale. Urban planning practice can operate within this construction, but largely interacts with Level Three – *Natural Ecosystems,* as interventions at the urban scale cannot be removed from the contexts in which they exist.

Waterfront open space exists at the urban scale and needs to perform different processes simultaneously: the maintenance of community by providing space that people can use for leisure and recreation; protection from physical harm by acting as a selectively permeable barrier to the water, and the modification and breaking down of inputs by filtering the air with its landscaped areas and remediation of the water at its edge. The multifaceted nature of open space need not adhere to such a rigid structure, but to learn how to improve the status quo of its implementation and pushing how space ultimately integrates within the built environment.

With that, Alexandris et al. offer a view of how bio-mimetic design processes are implemented in the developmental stage in their case, the designing of a new furniture product (2016). They define bio-mimetics as the practice of imitating the models, systems, and elements of nature in order to solve complex human problems. A seven-step methodology, seen in the following page, is employed to inform their design process. This framework offers "creativity and technical expertise" as drivers of innovation and argues that solutions found in nature will be more sustainable and have less impact on the environments in which they are placed. This argument aligns with similar viewpoints made in the field of landscape architecture[8] (Margolis and Robinson, 2007), but does not offer a method of viable implementation beyond the ideation stage.

[8] Margolis, L., & Robinson, A. (2007). Living systems: innovative Materialien und Technologien für die Landschaftsarchitektur. Basel: Birkhäuser.

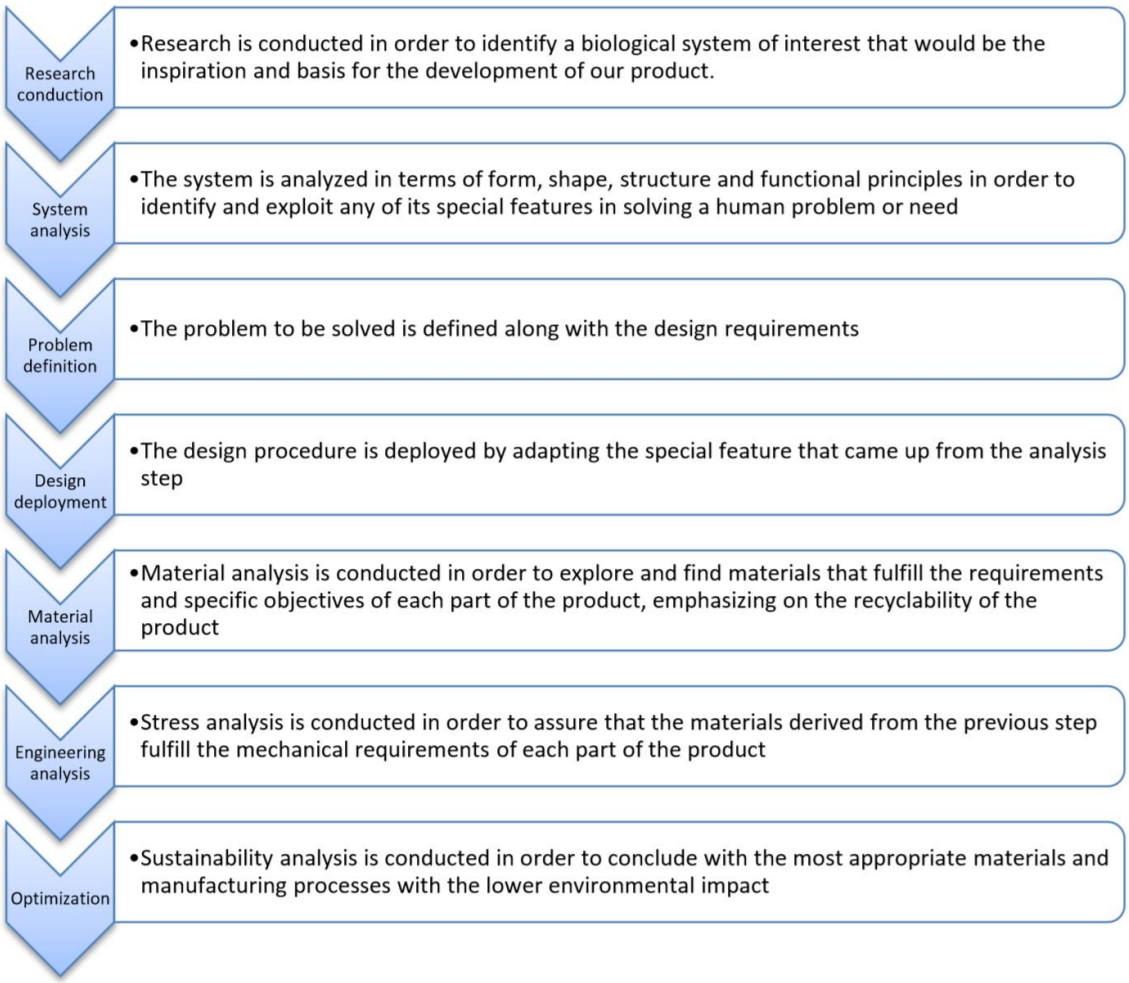

Figure 8: Biomimetic design process, Alexandris et al. (2016)

4.4.1 Theories of biophilia and restorative environments

McHarg's theory of "Dominate and Destroy" on modern industrialization and the environment, and Wilson's theory of the restorative benefits of nature on peoples' psyches can act as frameworks by which to compare the effectiveness of waterfront public spaces in New York City. If people are innately drawn to natural areas, then the collective biophilia of the people can be mobilized to deindustrialize waterfront public spaces by designing them to act more like nature. The New York City Environmental Justice Alliance of is a coalition of

grassroots organizations from low-income neighborhoods and communities of color that have been hit the hardest by both natural and human-made environmental disasters. Their NYC Climate Justice Agenda emphasized the growth of the green infrastructure industry in New York City, and argues that this shift in the economy needs to include communities that have been adversely affected by climate change. Inherent in the creation of waterfront public space is design, construction, and installation of materials in open space. If the planning framework of these spaces emphasizes inclusion of community in selecting and constructing nature-based bio-mimetic interventions, then both social and physical resilience can be built in the removal of nature-harming urbanization.

4.4.2 Bio-mimetic design strategies in planning

The final conceptual framework by which this thesis will define "bio-mimetic design" in urban planning practice then, is adapted from Biomimetics for Architecture and Design (Pohl and Nachtigall 2015), in which the act of discovering natural processes can be applied to wider fields than the exploration done by the Biomimicry Institute and Alexandris et al. This thesis further expands upon that definition and divides bio-mimetic design processes into two subcategories: "Restoration" and "Innovation".

Restoration looks at historical conditions of open spaces and aims to reengineer from their current conditions back into its pre-development stage. The daylighting of basins along the Gowanus Canal in South Brooklyn is an example of restoration. The restoration of underlying waterways mimics the landscape before hardscape interventions were introduced to create a working industrial waterfront and offers spaces of intervention to increasing area biodiversity

and remediation of publicly accessible waterways that have long been polluted. Rstoration assumes a prior, elevated state that can be reestablished through applied interventions.

To augment the ecological restoration approach of Lyle and McHarg, this paper will also look at second form of biomimicry, innovation, that focuses on developing new technology that is inspired by nature to interact with existing conditions in an effort to heighten sustainability and resilience. The development and implementation of concrete that mimics biological material in place of traditional concrete is an example of bio-mimetic innovation. Many companies claim that their product, while still hardscape concrete, can create new infrastructures on which flora and fauna can live[9,10]. Innovation is the change in paradigmatic processes through the intersection of other field of study. It is not, however, a future condition that can be reached, but an ongoing process that can be informed by the past and the future. This model of bio-mimicry is more commonly used in other fields of design such as industrial, product, and textile design (Das, 2015, Elena, 2014, & Alexandris et al. 2016). However, this comparison becomes limited in its scope with differing goals. For example, bio-mimicry in materials might value recyclability while bio-mimicry in planning may focus on permanent solutions to ever-changing problems. Sustainable design and architecture, then, are beginning to take a look at how hardscape and man-made structures can learn from nature (Hertzsch 2010 & Pohl and Nachtigall, 2015). Recent waterfront open spaces developed by DPR such as Hunters Point South Park and Brooklyn Bridge Park take inspiration from nature in their highly designed spaces[11]. This inspiration has

[9] Perkol-Finkel, S., & Sella, I. (n.d.). Econcrete Products. Retrieved from https://econcretetech.com/products/
[10] Yalcinkaya, G. (2019, January 31). Volvo creates Living Seawall to combat pollution and promote biodiversity. Retrieved from Dezeen: https://www.dezeen.com/2019/01/31/volvo-living-seawall-pollution-biodiversity-design/
[11] New York City Department of Parks and Recreation (2018) Design and Planning for Flood Resiliency: Guidelines for NYC Parks. https://www.nycgovparks.org/pagefiles/128/NYCP-Design-and-Planning-Flood-Zone__5b0f0f5da8144.pdf

only started to inform open spaces created by planning processes and needs to be further examined for feasibility.

Figure 9: Hunters Point South Park (A. Verceka, 2018)

The combination of these two biomimetic design strategies can be used to heighten the resilience of existing and future waterfront public spaces in New York by their integration within the planning processes that help create them. Scholarly focus on how natural ecosystems interact at transitional edges, especially at extreme conditions can guide how bio-mimetic design can be applied to cities' public spaces. Watson and Adams' book latches onto this restorative approach of bio-mimicry in the intersection of engineering and open space seen in Olmstedian flagship parks like Central and Prospect Parks. However, this tradition largely ignores more innovative,

but yet-to-be-proven work done in technology and material science fields of climate change resilience.

Furthermore, while natural spaces and bio-mimetic restoration often perform well in climate disaster scenarios[12], a full-scale application of emerging biomimetic technologies, like carbon-sequestering concrete and artificial trees that can support natural life, have yet to be proven successful in mitigating climate change at a larger city scale. This is not an uncommon gap in the field of biomimicry. Many design concepts are not built en masse which forces large-scale testing to rely on digital visualization and virtual performance monitoring to prove their worth.

That is not to say that physical planning mechanisms do not also have difficulty gaining a footing. For example, The Waterfront Alliance, a non-profit organization that focuses on waterfront development and protection in the New York Metro region has developed a points-based design system, the Waterfront Edge Design Guidelines (WEDG), which aims to create "resilient, ecological, and accessible waterfronts" (2018). WEDG suffers from similar criticisms to sustainable building practice's Leadership in Energy and Environmental Design (LEED) in that though they both offer a framework by which to benchmark a new development, they do not accelerate a systematic way of renovating or implementing environmentally sound design nor does the achievement of the current standards have a mechanism for post-installation performance in the longer term.

[12] David, W. (2019). Recreation and Resilience. National Recreation and Park Association Magazine, (January 2019). Retrieved from https://www.nrpa.org/parks-recreation-magazine/2019/january/recreation-and-resilience/

5. Findings + Recommendations

A thorough reading of literature and a delve into historical imagery regarding waterfront redevelopment, environmental policy, and bio-mimicry developed into an exploration of how New York City develops its waterfront public spaces. Site visits of these spaces created by Waterfront Zoning revealed a great deal of variance in physical condition and ability to be resilient in the wake of climate change and disaster.

Interviews with coalition leaders, design practitioners, academics and governmental agency directors further revealed deficiencies in current urban planning practice. Through these conversations, mechanisms where bio-mimetic design processes can be integrated into New York City's planning mechanisms were identified.

5.1 Historic conditions

Historic conditions were researched to identify possible strategies that could be reintroduced through modern bio-mimetic practices. Conditions of New York City's landscape and waterways were documented as early as 1782, when the British military took control of what is now known as Manhattan during the American Revolution. Seen on the following page is an illustration created during this era that reveals the natural land formations of Manhattan, parts of Brooklyn and New Jersey, as well as shorelines of Hudson and East Rivers.

Figure 10: Facsimile of British head quarters [sic] manuscript map of New York, Stevens (1782)

This map spurred the Bronx-based zoological organization Wildlife Conservation Society (WCS) to explore the former natural ecosystems conditions of New York in their Welikia Project. It aimed to reveal the biodiversity of the region prior to settlement and reclaim native Lenape narratives about the space on which they once lived[13]. In the Stevens' facsimile of New York and through research from WCS, it is known that land forms of New York City were chipped away by the constant ebb and flow of water from natural streams. Due to industrialization and the need to create housing to support the rapid economic growth, many of these inland streams were filled in and now exist only by name (e.g. Spring Street, Minetta Brook in Lower Manhattan).

Interspersed between the edges of all five boroughs along the banks of the Hudson and East Rivers were mudflats, salt marshes, and submerged forests. These edge conditions acted as habitats for remediating fauna such as bivalve mollusks that filtered out water pollutants, and

[13] Sanderson, E., & Boyer, M. (May 2013). Mannahatta: A Natural History of New York City. Harry N. Abrams.

seagrasses and trees that reduced wave attenuation. Waterfront public spaces on Staten and Randalls Islands have retained some features, but most were lost to urbanization. Waterways that are now subterranean were mapped by civil engineer Egbert Viele in 1865. These illustrations, commonly known as Viele maps, have continued to offer insight into contemporary planning and structural engineering practice. An example Viele map of Staten Island is shown below.

Figure 11: Sanitary & Topographical Map of Staten Island, Viele (1865)

Following the tradition of the Viele map, the Welikia Project superimposed the original shorelines of New York City onto aerial imagery captured by Google in 2019. Infill has notably shrunken the footprint of both the Hudson and East Rivers, limiting their capacity to hold water and magnifying the channeling effect towards sensitive areas. As illustrated in *Figure 1*, water will have to flow into built residential, commercial, and industrial areas in the event of a storm. This series of images helps recognize the limitation of waterfront public spaces to address a larger system-wide problem, but does not discount the ability to mitigate climate disasters for edge populations.

Figure 12: Aerial imagery of 2019 New York with 1609 shoreline in red, WCS (2013)

5.2 Current conditions

After Hurricane Sandy in 2012, DCP published a study on Coastal Climate Resilience that took stock of coastal geomorphologies in all five boroughs. We see that while they vary across the entire city, the majority were identified as having reinforced shorelines.

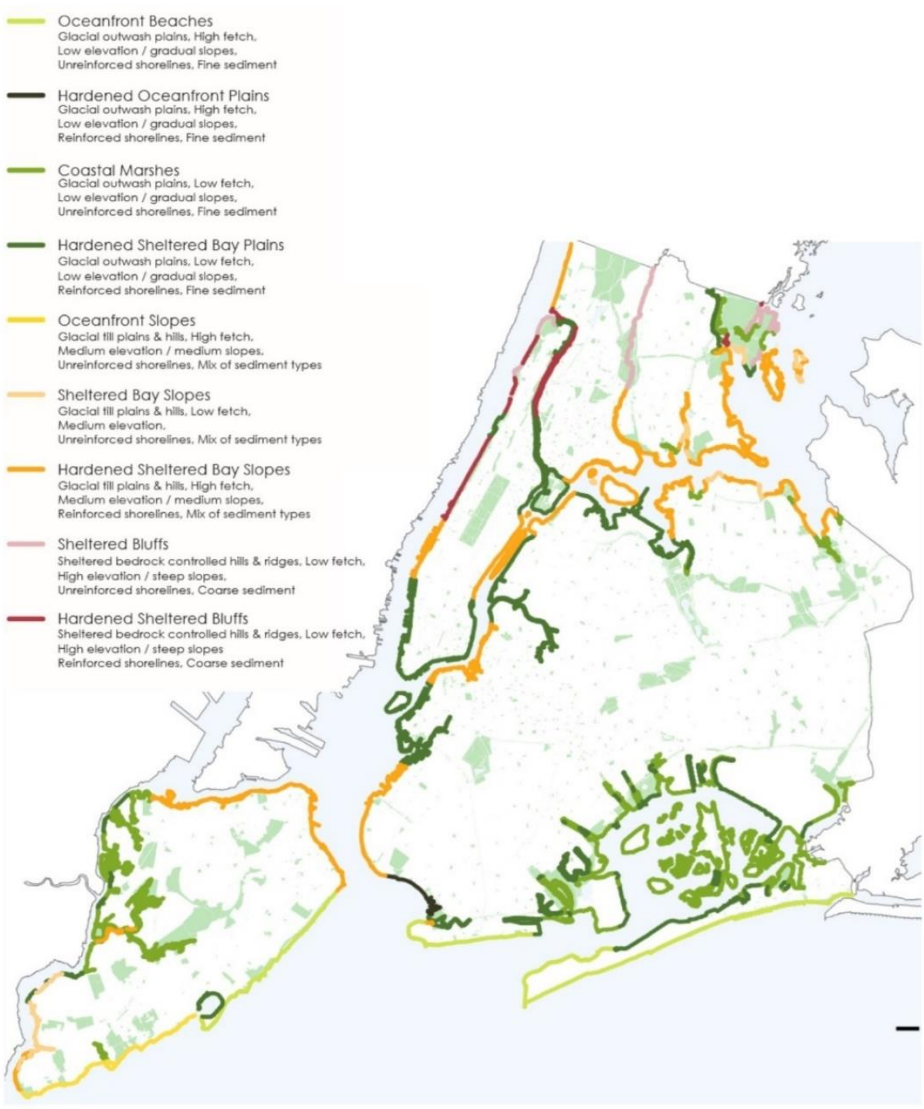

Figure 13: Coastal geomorphology categories, DCP (2013)

Figure 13 was used to understand choices made in the construction of waterfront public spaces that were created by redevelopment.

Below is a map that shows publicly accessible waterfronts as identified by DCP, shown in dark green. Areas outlined in yellow are future area of waterfront access, and areas in light green are spaces that are owned or operated by the Department of Parks and Recreation or by the State.

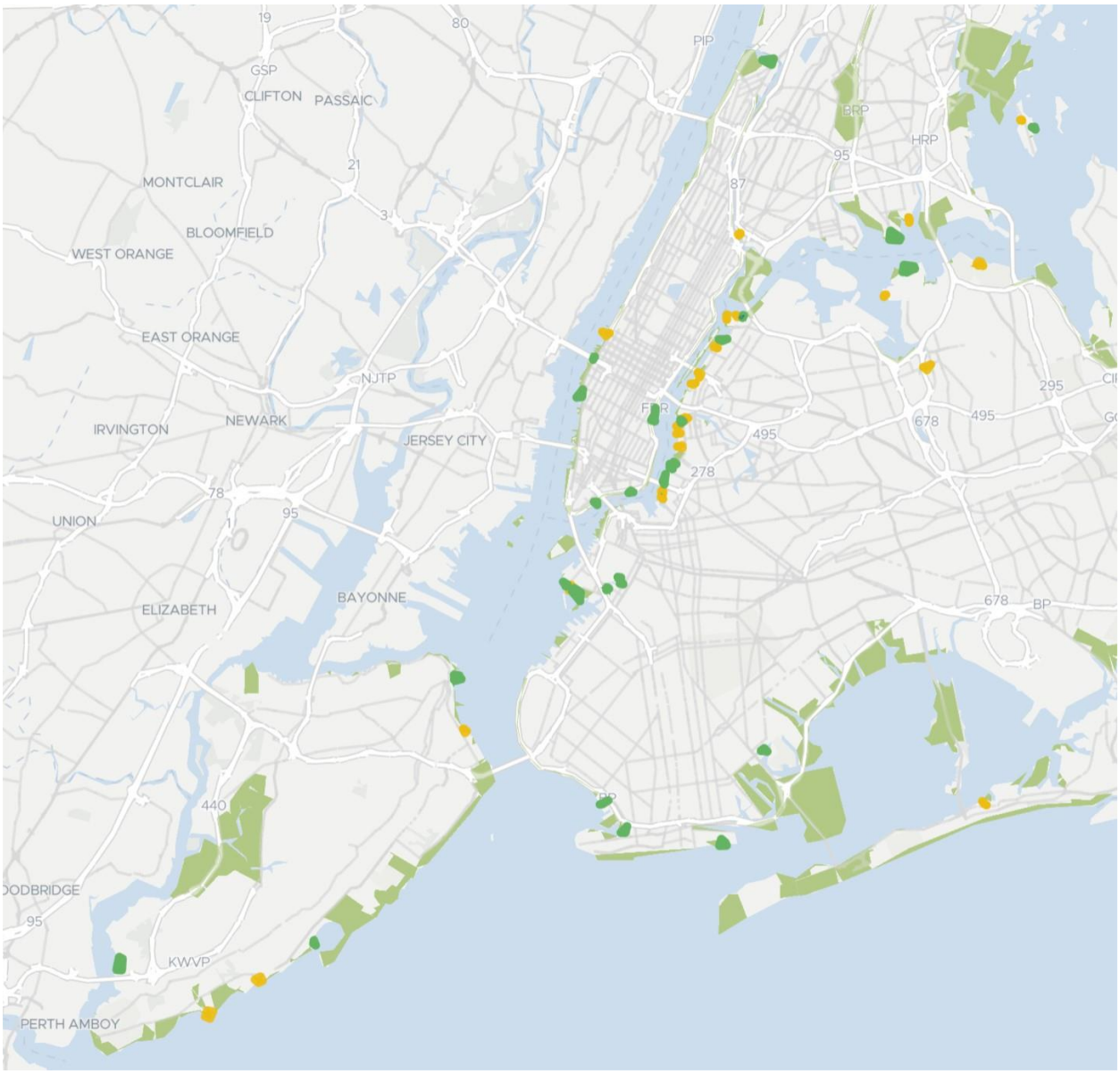

Figure 14: Waterfront Access Map, DCP (2018)

Areas that were targeted for development fell within the “Hardened Sheltered Bay Slope” geomorphology and consist of elevated and reinforced concrete shorelines. Recently introduced public spaces such as Domino Park in Williamsburg Brooklyn, and Pier 17 in the Financial District of Manhattan that were in an expectedly good condition, however, did not offer any insight into their climate resilient performance beyond elevation above their adjacent waterway.

Waterfront public spaces that were constructed prior to Hurricane Sandy were varied in condition. For example, the public esplanade provided by the Waterside Houses and Plaza development by Stuyvesant Town in Lower Manhattan was completely inundated by storm water during Sandy due to the elevation chosen for the fill and the concrete site’s inability to filter water away after the storm. Site owners repaired the esplanade after the storm but offered little to no improvement to the mitigative ability of the space itself.

Figure 15: Waterside Houses Esplanade along the East River, DCP (n.d.)

5.3 Best practices for future conditions

If waterfront open spaces provided by Waterfront Zoning are built to a climate mitigative standard that no longer adequately defends the residents of nearby development, what processes can and should be retroactively applied to these spaces that are at risk of underperforming by increasing margins?

5.3.1 Methods of bio-mimetic restoration

Through the promotion of native species and emphasizing biodiversity, planning relinks people to nature even under the premise of redevelopment.

Sanderson offers a framework by which New York City designers could implement bio-mimetic restoration, including an extensive list of native plants that could be prioritized for their ability to adapt to the changing conditions. For example, native seagrasses tolerate excess water and drought better than non-native counterparts. Commonplace turf grasses have shallower roots than their native counterparts, meaning that more soil would be destabilized in the event of a flood. This reintroduction of native plants that can better handle stormwater while providing mitigation to the urban heat island effect is currently happening through the re-introduction of wetlands along the New Jersey shoreline of the Hudson River as well as in DPR properties in the East Bronx, South Brooklyn, and Staten Island.

A notable restoration of native plantings and indigenous landscapes can be found on the waterfront of Randall's Island. The island, jokingly regarded by an interviewee as "Robert Moses' unfulfilled dream for New York," once was home to swathes of hardscaped areas that were used to hold debris from other areas of New York. In recent years, local non-profits have worked to restore the tidal salt marshes that existed on the island periphery. These marshes are

noted to be some of the most productive ecological systems on Earth measured by the rate at which native plants undergo photosynthesis[14].

This research recognizes that Randalls Island's unique operation is largely under the jurisdiction of DPR. However, its transformation from industrial holdings to a biodiverse recreational area makes for a compelling case study for restoration as a viable model in waterfront redevelopment and climate change mitigation.

[14] Mitsch, W.J. & Gosselink, J.G. (1993). *Wetlands.* New York: Van Nostrand Reinhold.

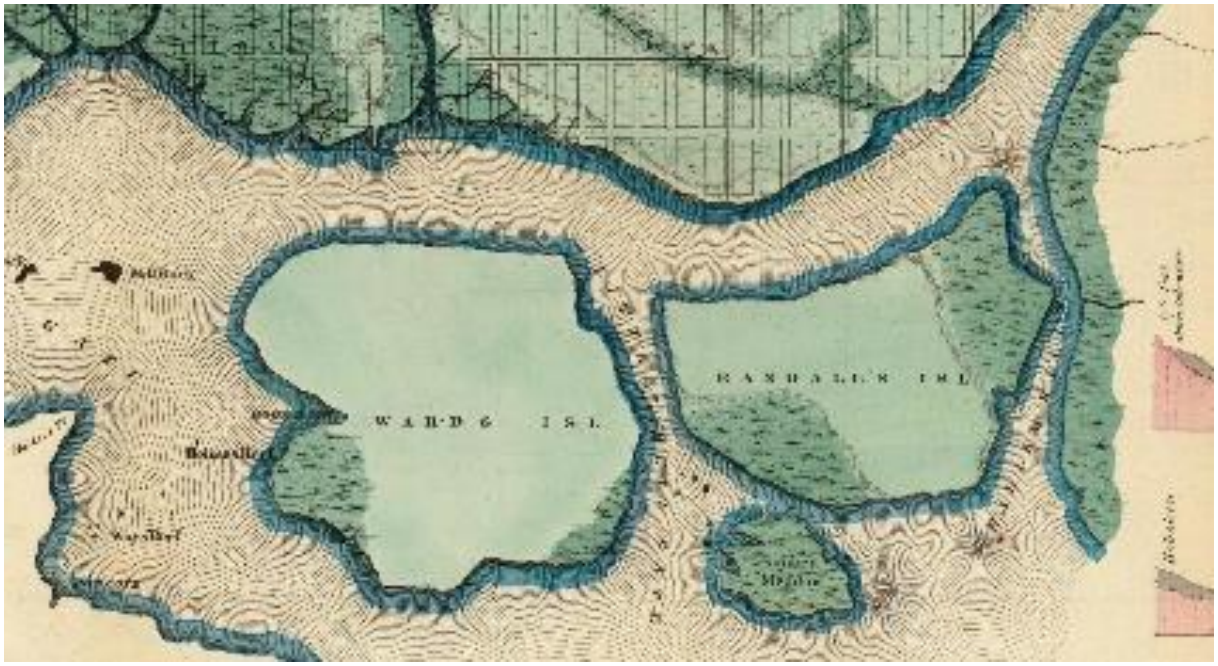

Figure 16: Extent of wetlands on Randalls Island, Viele, (1865)

Figure 17: Tidal salt marsh on Randalls Island, Great Ecology (2017)

In regard to the restoration of native fauna, a series of projects have been launched in the last decade. Most notably, the Billion Oyster Project, a non-governmental organization, is working to restore the oyster reefs that once played a big role in environmental protection of New York Harbor. It is known that waterways that are inhabited by oysters have cleaner water due to the oysters' filtration of nitrogen. The reintroduction of these oysters is being done in select areas where they were indigenous such as the South Shore of Staten Island and within the Hudson. This is done on a variety of structures including piers that make use of the aforementioned "Econcrete" which will act as a habitat that encourages natural reproduction.

The reintroduction of other native aquatic fauna has not been attempted at this scale, but the Billion Oyster Project reports that this is a process that will naturally increase biodiversity because of the cleaned water. Only time will tell if this form of bio-mimetic restoration of species will increase system-wide resilience.

5.3.2 Methods of bio-mimetic innovation

Because bio-mimetic innovation has yet to be done at an urban scale, innovation at the moment exists as a combination of natural process into a single artifact. It is, then, the assemblage of these smaller scale artificial interventions that needs to be explored as opposed to the designing of a whole space under one form of bio-mimicry. As mentioned in the conceptual framework, AskNature's Biomimicry Taxonomy offers a vocabulary that community members, designers, and government agencies can adopt when testing this method of bio-mimicry within their public spaces. As this model has not been broadly applied in the United States, let alone in New York City, international examples were explored for guidance on how to mimic nature to increase the resilience of waterfront public spaces.

Innovative bio-mimetic product design can be applied at the urban scale. One form that was explored was the Living Seawall project out of the Sydney Institute of Marine Science and Reef Design Lab, in collaboration with Swedish automotive manufacturer Volvo. By mimicking the root structure of mangrove trees, seen in Figure 18, Living Seawall attenuates wave action by attracting oysters and mollusks that are native to Sydney's harbor. The tiles that are attached to the seawall are 3D-printed using marine concrete and recycled plastics. As of February 2019, 500 have been mounted onto existing structures at Milsons Point in Sydney, Australia and will act as a pilot study of increasing biodiversity vis-à-vis bio-mimetic innovation.

Figure 18: Mangrove trees and roots in Palawan, Philippines (n.d.)

Figure 19: Living Seawall tile, Sydney Institute of Marine Science (2019)

At a larger scale, we see construction of synthetic landforms that mimic natural geomorphologies in the context of East Asian countries that are experiencing rapid urbanization and a dearth of developable space. Design practitioners have communicated their concerns over the lack of open space provided in this new paradigm of growth. This can be seen in the Hainan province of China, a low-lying archipelago off the southern shore of the mainland in the South China Sea. Here, the rapid growth of tourism and the commercial sector prompted rapid residential construction. However, with global climate change, the region also started experiencing stronger, more frequent monsoons that were damaging the archipelago's infrastructure. The municipal government ran a design competition for a master plan for one of the islands, where the proforma had specified 70 percent built and 30 percent "natural" or vegetative space for the selected island. A notable proposal entitled South Sea Pearl Eco-island from New York-based architecture firm Diller, Scofidio + Renfro flipped the given project ratio, emphasizing nature-based solutions to climate events through an integration of innovative bio-mimetic strategies such as forming a pseudo-volcanic caldera for island protection.

Calderas are collapsed volcanic chambers that stay above sea level. Due to this elevated state, water can be kept within the caldera itself and kept out in the case of flood inundation. Furthermore, natural geomorphologies, like calderas, allow for the growth of ecological assemblages in a way concrete does not. In the case of Hainan, the constructed caldera was not dissimilar to the existing ecology of surrounding islands and will allow for native plants to take root over time, even as climate conditions change.

Figure 20: Example of a natural caldera at Crater Lake, OR, National Geographic (2013)

Figure 21: Rendering of South Sea Pearl Eco-Island proposal, Diller, Scofidio + Renfro (2016)

This approach to reconstruct space using ancient technology where it did not exist is one method of innovation on the status quo of infill and elevation. However, a recognition of different governmental structures between China and the United States as well as the tabula rasa nature of the South Sea Pearl Eco-Island development that allowed for innovative bio-mimetic exploration must be noted. Both limitations necessitate a deeper delve into New York City's governmental structures that would allow for or prohibit integration of these strategies, no mater how well they perform.

5.3.3 Hybrid approach

The gap in bio-mimetic research at the city scale presents an interesting opportunity to remediate public spaces identified by the community as under-performing or deficient by treating them as testbeds for emerging technologies. Some planning processes in New York are beginning to use bio-mimetic restoration and innovation processes. The DCP Gowanus Planning framework identifies ecologically performative landscapes that mimic former edge conditions of the waterway and can be applied as the EPA intervenes and begins to clean the pollution within the Canal.

A theoretical hybrid approach applied to this scenario could start with the reintroduction of stream networks that would purposefully flood when inundated with water and innovate through integration of new technologies such as membrane bioreactors to filter contaminated flood water. One such project in Gowanus is looking at this approach of restoration through new technologies. DLAND Studio is aiming to help restore the Gowanus Canal through the construction of Sponge Park. Flood tolerant native plantings line the edges where the park and the polluted waters of the Gowanus canal meet and act as the restoration of landscapes lost to

industrialization. These plantings work in tandem with an engineered filtration system that allows flood water to be diverted away from nearby development. This system mimics the wetlands that were interspersed between tributaries of the original Gowanus Creek.

This hybrid approach recognizes the inability to erase the ills of the past. It is not the responsibility of planning and design to replace all hardscape solutions, especially where they are needed. The approach taken by the designers of Sponge Park illuminate the untapped potential of bio-mimetic strategies that can be incorporated into a planning framework which is discussed in the following section.

Figure 22: Gowanus Sponge Park Plan, DLAND (2010)

5.4 Reimagining the governmental status quo

5.4.1 Rethinking waterfront planning

New York City Waterfront Zoning dictates the required area of planted space and number of canopy and ornamental trees that need to be provided in any public space created by private development that is adjacent to a body of water. Without these regulations, public spaces would not have to be provided by waterfront development, nor would they have to adhere to design rules. However, its current language is devoid of regulation regarding the enhancement of ecology beyond the installation of in-water structures like bulkheads and piers.
In this way, biomimetic restoration is unable to be incorporated into planning processes at the municipal level.

This does not preclude an exploration of biomimetic innovations by DCP as it would not be the first time emerging technologies will have affected the *Zoning Resolution* through the input of community members and non-governmental parties. In 2011, green infrastructure technologies such as the implementation of sun control devices, vegetated roofs, and alternative energy installations were codified in the Zone Green process under the Bloomberg administration. This process was spurred by the difficulties in implementing then-emerging technologies and revised prohibitive language in the zoning's building practices.

The prescriptive nature of the Waterfront Zoning may have room to adjust to and promote the use of evolutionary bio-mimetic technologies on built spaces. For example, an expansion of terminology to base materials and amenities on performance-based standards, as opposed to prescribing precise measurements, will allow for flexibility in the design of these spaces.

Unfortunately, as Waterfront Zoning is triggered by redevelopment, this ties the outcome to whatever the market decides is economically viable, as opposed to environmentally resilient.

However, there is a palpable optimism within the design community and municipal agencies that resilience and economic benefits will soon overlap which may be enough leverage to edit prohibitive language in the Zoning Resolution. A layered approach can also be taken with a revision of the City Environmental Quality Review. CEQR may be the right target for short-term intervention. If City Planning were to grow the Waterfront Revitalization Plan Consistency Assessment to include "resilience" strategies that look to strengthen waterfront spaces as opposed to just "adaptive" strategies that seek to accept changing conditions, the growing field of biomimetic innovation would have more footing as new technologies claim to solve the ills of the past adaptation. If we accept that climate change is continually moving the goal post of what is environmentally sound, then review processes and the projects that are created also need to be mindful of potential changes, especially when there are structures and lives at risk.

This research comes at the cusp of New York's municipal agencies understanding that the status quo of waterfront design has not acted the way that it needed to in times of disaster. The Mayor's Office has started to convene its Waterfront Management Advisory Board that seeks to guide the 2020 Comprehensive Waterfront Plan. Board members that were interviewed were optimistic that they could plant incremental seeds of change based on conversations with their community constituent groups. It is encouraging that conversations are putting community needs at the forefront, but there needs to be greater cross-pollination with waterfront planning and emerging research happening in urban design and technology.

5.4.2 Championing the efforts of local non-profit organizations and coalitions

Candor from regulatory agents revealed how State DEC's priority is to avoid, minimize, then mitigate climate-related events in that order. Due to this rigidity of state policy, city officials report that in-water interventions are difficult to permit as avoidance of waterway disruption is preferred over mitigating the effects of climate change.

Acceptance of the idea of biophilia allows for the exploration of mobilizing human power in the implementation of bio-mimetic design processes to creatively work with DEC's perceived unwillingness to strengthen the waterfront. Translating the community needs of resilience starts with access to quality waterfront spaces and opportunities for communities to get involved. Strong environmental justice organizations with eager community members already exist in each of the five boroughs. They develop plans and identify both design-oriented and governmental partners that can help bring their ideas for environmental remediation to life (South Bronx Unite 2017, WE ACT 2016). However, coalition leaders report that much of the interaction between their respective organizations and traditional avenues of planning at the state level only happens during the beginning of projects. Contemporary planning mechanisms congratulate themselves on their ability to engage people during the master plan and design ideation stages. However, state representatives will argue that this is where innovation in design happens: through fostering iterative conversations with community members.

However, once a plan is underway, the communities and coalitions generally have no physical input. If the first goal of the City and State's joint Comprehensive Waterfront Plan is to reconnect people to their waterways via public access, then participatory community waterfront restoration should be implemented beyond the ideation stage. Like the New York City DPR TreesCount! volunteer program, collective action, and stewardship would allow people to take

ownership of their waterfronts while offering an educational opportunity in which concepts of bio-mimetic design, climate action, and environmental justice can be better communicated.

In a similar vein, coalitions are circumventing state environmental policy. This is seen in the implementation of alternative energy installation within public housing in a South Bronx neighborhood. The same local non-profit has also been fighting for environmental justice in a community that has long been an industrial port for the city. State interventions have systematically cut off this neighborhood from its waterfront that was described as "a stone's throw away," and organization leaders are now seeking to replicate their success in alternative energy production in their efforts to reconnect their residents to the waterfront. The Climate and Community Protection Act is a good first step by the state to realize its goals of environmental sustainability and equity. However, as the bill awaits its approval, community members are already laying down the groundwork for resilient waterfront projects in their neighborhoods without the State's approval. The state needs to explore ways to prioritize the lived experiences of community members and legitimize the efforts made to tackle systematic disenfranchisement.

One way it can do so is through an integration of citizen science and stewardship programming within its agencies. Bio-mimicry offers a provocative way of increasing a community's environmental literacy through these models of engagement. Planning for waterfront public spaces can encourage a citizen science model like the 2015 TreesCount! Program through the State Urban Forestry Council and DPR, where staffers learned about the value of street trees through enumeration. Beyond the government-required public review period, government agencies can also encourage volunteer stewardship of waterfront spaces as they become cleaner and more accessible. DPR jointly runs It's My Park Day with advocacy organization Partnerships for Parks where community members are encouraged to take

ownership of their parks through beautification processes. Communities that have actively been discouraged from participating in these processes have already made strides into offering these models of engagement. It is now the turn of government processes to recognize and legitimize these efforts.

5.5 A need to build political will

Design practitioners and academics, as well as non-governmental organization leaders were highly critical of each of the governmental practices discussed above. The glut of political processes exponentially expands when the jurisdiction is unclear. This is especially true of in-water interventions as presented in this thesis, where governmental bodies range from the municipal level with enforcement of public amenities, all the way to the federal level when looking at the region as a whole. With this difficulty of overlapping jurisdictions in mind, the process by which community members and their respective coalitions present their local needs to several legislative members was described as a laborious process, even with topics as urgent as climate action. A member of a non-governmental organization described the process as "spoon-feeding legislators every step of the way to get policy that is fifteen years too late."

This is illustrated in the Build It Back Program, operated by the NYC Mayor's Office of Housing Recovery Operations and funded by the US Department of Housing and Urban Development's Community Development Block Grant for Disaster Recovery.

6. Discussion + Conclusion

This thesis was to be an exploration of the efficacy of bio-mimetic design, but it evolved into the convening of government bodies that need to keep pace with the rapidly evolving fields of design and technology. This is as a result of a realization that it almost does not matter how

design processes and functions work in a laboratory setting if the governmental framework does not know how to support them in urban practice. Planning processes, whether they be top-down like the imposition of USACE projects in the New York-New Jersey harbor, or participatory like the DCP Planning Framework for Gowanus, only get pushed in the direction of resilient design because of the interaction of strong coalitions, formed by community-based non-governmental organizations.

In the context of New York City, open spaces have been highlighted for their ability to "ameliorat[e] the public health impact of climate change (Benton-Short, et al., 2014), but as analysis and interviews have proven, are seen as ancillary to solving the problem of climate resilience when compared to hardscape interventions that seem to offer effective solutions in the short-term.

With that in mind, the federal government understands that green infrastructure has the ability to "restore some of the natural processes require[d] to manage water and create healthier environments" but offer no real recommendations as to how to better implement urban sustainability plans at a national, or even regional scale (EPA, 2014). A lack of a common metrics to determine what benefits arise from implementing green infrastructure at this scale, especially emerging bio-mimetic design strategies of restoration and innovation are a major detriment to why we are unable to move forward. Designers, planners, and community coalitions all operate with dissimilar vocabularies which is not necessarily a bad thing. But that means it requires careful communication between the parties to best implement strategies that address both community needs and conceptual imaginaries that will help make bio-mimetic design strategies commonplace in a city as innovative as New York.

Furthermore, the current paradigms by which we construct our built environment need to change. It is evident that there are infill developments and public spaces that can perform well under current storm conditions. But as proven by climate scientists time after time post-disaster, the effects of climate change are a moving goal post. Hardscape interventions made in the past are not guaranteed to work the way they have done historically. However, with millennia of experience with the ever-changing climate, natural processes have their way of prevailing against even the worst conditions. If New York City can begin to understand how these bio-mimetic design processes work in the larger setting of its waterfront public spaces based on performance-based standards within planning mechanisms at all scales of government and community, then it can build upon its physical and social resilience.

7. Appendix

7.1 List of Figures

7.2 List of Interviews

- Professor, Columbia University
- Director, Diller Scofidio + Renfro
- Manager, The Nature Conservancy
- Director, NYC Department of City Planning
- Program Coordinator, NYS Department of Environmental Conservation
- Director, Our Climate
- Professor, Pratt Institute
- Vice President, Regional Plan Association
- Director, South Bronx Unite
- Manager, WE ACT for Environmental Justice
- President, Waterfront Alliance

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